Psychological Reports, 1961, 9, 151-161.

ON PRIOR INFORMATION AND CREATIVITY

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The background for this experiment can be put into the form of a question: "How is the way you solve a problem influenced by knowing what others have done?" The answers to this question express two different viewpoints.

According to one viewpoint, you should know as *much* as possible about how others have tried to solve the problem before you tackle it. According to the second viewpoint, however, you should know as *little* as possible about how others have tried to solve the problem before you tackle it (to avoid being misled by their preconceptions).

Both viewpoints emphasize the content or the amount of what you know. But whether prior information helps or hinders your problem solving may depend, not so much upon its content, but rather upon how you originally stored it. The present experiment begins with the hypothesis that both the *content* of your prior information *and* your *attitude* toward this content when you stored it combine to determine the outcome of your solution.

Although the emphasis on prior information, as input, connects the present experiment with studies on "preparation" or "transfer" (cf. Duncan, 1959; Johnson, 1955), the use of creative problem solving, as output, differentiates the present experiment from the classical studies of problem solving. In "classical problem solving" an answer is either "correct" or "incorrect"; *S* has to discover a response that will satisfy explicit and immediately apparent standards of acceptability. In "creative problem solving" there are no "correct" or "incorrect" answers. Rather, the wide range of possible answers are more or less adequate, more or less successful; *S* not only has to discover possible responses, but he also has to choose from among them in terms of vague, often unverbalizable, standards. Indeed, the possible answers may vary on a number of subjective continuua, and the degree to which a response succeeds, i.e., its creativity, depends upon how well it satisfies the standards, often implicit, of some designated subculture.

Such creative problem solving, which more closely simulates the situations which scientists, engineers and laymen face in their every-day problem-solving, has received little attention in the psychological laboratory. But creative problem solving has been widely discussed by many writers and scientists, who often advise their readers on how to achieve better solutions. Much of this advice focuses upon the gathering of information during the preparatory phase.

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Patrick (1955), for example, quotes scientists and writers who advise the thinker to accumulate abundant information before attacking a problem. After discussing the possibility that prior information "makes it difficult to find a new and fruitful approach," Beveridge (1957), nevertheless, concludes "that it is a more serious handicap to investigate a problem in ignorance of what is already known about it." And Wilson (1952) warns that "six hours in the library may save six months in the laboratory."

But Jewkes, Sawers, and Stillerman (1958), who also examine the effects of prior information, come to a conclusion opposite to that of Wilson and Beveridge. They argue that "the less . . . an inventor is pre-committed in his speculations by training and tradition, the better chance of his escaping from the grooves of accepted thought. The history of invention provides many instances of the advantages, if not of positive ignorance, at least of a mind not too fully packed with existing knowledge or the records of past failures."

Because these two seemingly opposite views, that prior information helps or that it hinders, have been stated in rather broad and abstract terms, it is possible that both, when properly qualified, may be correct. For this *E*, the two viewpoints pose the following question: "Under what conditions does prior information facilitate, and under what conditions does it hinder creative problem solving?" Rephrased in terms of a possible experimental inquiry, the question might become, "Can we find situations under which given information helps and under which it hinders creative problem solving?"

The type of information, its content and amount, appears to be an obvious condition which can be examined experimentally. In addition to the type of information, the conditions under which *S* receives the information is another possible experimental variable, one which is suggested by Beveridge in his attempt to reconcile the two different views toward prior information.

> The best way of meeting this dilemma is to read critically, striving to maintain independence of mind and avoid becoming conventionalised. Too much reading is a handicap mainly to people who have *the wrong attitude of mind*. Freshness of outlook and originality need not suffer greatly if reading is used as a stimulus to thinking and if the scientist is engaged in active research (Beveridge, 1957, p. 6. Italics added).

As far as this *E* is aware, the only investigator to study experimentally the effects of "attitude of mind" upon subsequent creative problem solving is Torrance (1959), whose experiment will be discussed later in this paper.

The present experiment, then, can be looked upon as a first attempt to see how information and *S*'s attitude towards this information affect creative problem solving. The information was varied by exposing *S* to four answers that other engineers had given to an Automatic Warehousing Problem;[2] one

[2] The Automatic Warehousing Problem originated as an actual manufacturing task within a component of the General Electric Company. This *E* adapted the present version of the problem from an assignment that had been employed in two previous Creative Engineering Courses. He is indebted to Daniel Johnson of the General Engineering Laboratory for help in the selection and wording of the problem.

set of answers contained overlapping or homogeneous answers and the other set contained non-overlapping or heterogeneous answers. *S*'s attitude toward this information was varied by requiring him either to evaluate constructively the given answers (list advantages for each) or to evaluate them critically (list weaknesses for each). The combined effects of the information and the evaluation were examined in terms of *S*'s subsequent solutions to the same Automatic Warehousing Problem and to a new, unrelated problem.

METHOD

Subjects.—*S*s, who were 36 newly-hired, male engineers, ranged in age from 21 to 29 with a median of 22.6 yr. *S*s all had degrees in electrical engineering with the exception of three whose degrees were in physics.[3]

Experimental conditions.—*S*s were divided into four groups of equal size, each group being assigned to one of the four experimental conditions shown in Table 1. The independent variables, type of information and type of evaluation,

TABLE 1
EXPERIMENTAL CONDITIONS

Information	Evaluation	
	Constructive	Critical
Homogeneous	HOCO List advantages; 4 similar solutions	HOCR List weaknesses; 4 similar solutions
Heterogeneous	HECO List advantages; 4 different solutions	HECR List weaknesses; 4 different solutions

were manipulated by means of an evaluation task. In this task, each *S* was asked to evaluate four answers that other engineers had previously given to an *Automatic Warehousing Problem. After receiving* a *printed description* of the problem, *S* was told that his task was to evaluate, one at a time, each of the four proposed solutions.

The information variable consisted of two different sets of four answers: The Homogeneous Set (HO) contained four very similar or overlapping answers (the answers referred to different ways of marking the boxes (with a color code, magnetic material, radioactive paint, or patches of light-reflecting material); the Heterogeneous Set (HE) contained four different and non-overlapping answers (solutions were based on screening for physical size or shape, reflectance of the box's surface, dielectric properties of the box's contents, and positioning of the boxes on the conveyor). The evaluation variable included two different ways in which *S*s were requested to respond to the four answers. In the Constructive Condition (CO), *S* was asked to "list as many

[3]*S*s were supplied by the Engineering Education Service of the General Electric Company, who also contributed in other ways to the conduct of this experiment.

good features and benefits" as he could for each answer. In the Critical Condition (CR), *S* was asked to "list as many faults and problems" as he could for each answer. *S* was given 5 min. to evaluate each answer, a total of 20 min. for the entire task.

Experimental tasks.—Immediately after they had evaluated the answers to the Automatic Warehousing Problem, *Ss* were handed a new booklet in which they were asked to propose their own solutions to this same problem. In brief, the Automatic Warehousing Problem required *S* to devise a system which would automatically recognize boxes to comply with certain specifications. For this problem, as well as the next one, *S* gave his responses in two stages or phases: in the Production Phase *S* was asked to list as many different ways as possible to recognize the boxes (10 min.); in the Solution Phase, he was asked to choose his best solution and briefly develop it in more detail (10 min.). The inclusion of the Production Phase was an attempt to get information about what alternatives *S* considered before he arrived at his solution.

As his final task, *S* was asked to devise an application for the Pyroelectric Effect (Hix & Alley, 1958, pp. 173-174), which is a little known physical phenomenon. The effect refers to the charges which appear at the ends of certain crystals when their temperature is changed. This task, which differs from the Automatic Warehousing Problem both in content and type, was included to see to what degree the experimental effects might transfer beyond the specific situation to which the prior information was relevant. In the Production Phase (10 min.) *S* was asked to suggest as many possible applications as he could for the Pyroelectric Effect. In the Solution Phase, *S* was asked to select his best suggestion and develop it in detail (5 min.).

After the Solution Phase of each problem, *S* was asked to rate the degree to which he was satisfied with his chosen solution.

Ss within any one experimental group met at the same time and worked on the tasks in a large conference room. The four different groups met at four different times on the same day in the same conference room.

Results

Rating of the final solutions.—The final solutions to both experimental problems were rated for creativity in terms of standards set up by engineers who were familiar with the problems. Each of the 36 solutions to the Automatic Warehousing Problem from the present experiment was matched with its closest equivalent in a standard set of previously rated solutions. Each solution was then assigned the same rating as that which had previously been given to the standard solution with which it was matched. The estimated inter-rater reliability for this standard set of ratings is .85.

The solutions to the Pyroelectric Effect, identified only by numerical codes, were given to three engineers to rate for creativity. The judges, working in-

dependently and with no knowledge of the experimental conditions under which each solution had been obtained, sorted the answers into five degrees of creativity according to their own standards. Because the ratings of one judge correlated — .14 and — .32 with those of the other two judges, they were discarded on the grounds of unreliability. The ratings of the other two judges, which correlated .86 with each other, were pooled to form a set of judgments with an estimated reliability of .93.

A content analysis of the final solutions to the Pyroelectric Effect Problem helped to explain why one judge differed from the other two. The two "reliable" judges agreed in rating at the low end of the creativity scale each answer that involved using the crystals as temperature sensors. These two judges also agreed in rating at the high end of the scale those answers which avoided temperature sensing or regulation. Thus, these judges seemed to be employing, firstly, an originality criterion (only unusual or unconventional answers were classified at the high end) and, secondly, a quality criterion (an elaborated answer typically got rated a step higher than a similar answer that had less detail). The third judge, however, seemed to employ only a quality criterion (those answers that were accompanied by specifications of how they were to be implemented were rated high in creativity); those answers that were vague or lacked specifications were rated low in creativity. Thus, this latter judge rated some temperature-sensing answers as "1" and other temperature-sensing answers as "5" (whereas all such answers were rated either "4" or "5" by the other two judges). This same judge gave low ratings to many unconventional answers (answers that were rated "1" by the other judges) presumably because they were vague on how they were to be implemented.

Final solutions to the Automatic Warehousing Problem.—Table 2 shows the mean ratings on creativity for the solutions to the Automatic Warehousing Problem. The rating scale ranges from "1", indicating the lowest degree of

TABLE 2
RATED CREATIVITY OF FINAL SOLUTIONS TO AUTOMATIC WAREHOUSING PROBLEM FOR EACH EXPERIMENTAL GROUP (N = 9 *Ss* PER GROUP)

Information	Evaluation	
	Constructive	Critical
Homogeneous	3.44	2.67
Heterogeneous	3.06	2.06

creativity, to "5", indicating the highest degree of creativity. Table 3 reveals the results of an analysis of variance of these creativity ratings.[4] Only the

[4]The analyses of variance for both the Automatic Warehousing Problem and the Pyroelectric Effect Problem were conducted upon the *sum of* two ratings from two independent judges. Thus, the mean squares in Tables 3 and 4 are four times greater in magnitude than they would be if the analyses had been conducted on the average ratings that are

TABLE 3
ANALYSIS OF VARIANCE OF RATINGS ON CREATIVITY FOR THE AUTOMATIC WAREHOUSING PROBLEM

Source	*df*	*MS*	*p*
Evaluation	1	28.44	.05
Information	1	9.00	
Interaction	1	0.44	
Within groups	32	4.83	

effects of evaluation are significant. The Constructive Condition resulted in solutions which were rated higher on creativity.

Final solutions to the Pyroelectric Effect Problem.—Table 4 is of special interest because it shows the effects of the evaluation task upon creativity in

TABLE 4
RATED CREATIVITY OF FINAL SOLUTIONS TO PYROELECTRIC EFFECT PROBLEM FOR EACH EXPERIMENTAL GROUP

Information	Evaluation	
	Constructive	Critical
Homogeneous	2.78	2.39
Heterogeneous	4.00	2.56

an unrelated problem. As Table 5 reveals, the Constructive Condition, in agreement with its effects in the previous problem, results in solutions which were rated higher on creativity than those from the Critical Condition.

TABLE 5
ANALYSIS OF VARIANCE OF RATINGS ON CREATIVITY FOR THE PYROELECTRIC EFFECT PROBLEM

Source	*df*	*MS*	*p*
Evaluation	1	30.25	.05
Information	1	17.36	
Interaction	1	10.03	
Within groups	32	6.33	

Although the informational input is again not significant, there is a suggestion that in this problem the Heterogeneity Condition may facilitate creativity ($p = .10$ by a two-tailed test).

The Production phase.—Tables 6 and 7 show the mean number of suggestions for the Automatic Warehousing and Pyroelectric Effect Problems, respectively, which *Ss* in each experimental condition were able to list during

presented in Tables 1 and 2. The variance ratios and tests of significance, of course, are not affected by this change in scale.

Non-parametric analyses of variance by ranks, which were also conducted on these same data, yielded identical conclusions—only the effects of evaluation are significant at the .05 level for both problems.

TABLE 6

MEAN NUMBER OF ALTERNATIVE SOLUTIONS PER GROUP SUGGESTED FOR AUTOMATIC WAREHOUSING PROBLEM DURING PRODUCTION PHASE

Information	Evaluation	
	Constructive	Critical
Homogeneous	6.11	3.22
Heterogeneous	5.67	5.11

the Production Phase. An analysis of variance performed on the transformed number of solutions (the Freeman-Tukey square-root transformation, Mosteller & Bush, 1954), reveals that the effect of evaluation falls just short of an acceptable level of significance in the Automatic Warehousnig Problem ($p =$ .08; two-tailed), whereas it is significant ($p = .01$; two-tailed) in the Pyroelectric Effect Problem. In both instances, the Constructive Evaluation resulted in a greater number of suggested solutions. Neither the informational variable nor the interaction was significant for either problem. Thus, the Constructive Condition, when compared with the Critical Condition, appears to increase the number of suggestions which *S* puts down during the Production Phase.

TABLE 7

MEAN NUMBER OF ALTERNATIVE SOLUTIONS PER GROUP SUGGESTED FOR THE PYROELECTRIC EFFECT PROBLEM DURING PRODUCTION PHASE

Information	Evaluation	
	Constructive	Critical
Homogeneous	5.33	3.56
Heterogeneous	4.22	3.22

Interrelationships among the variables.—The Pearson product-moment correlation coefficient was computed from the pooled within groups sums of squares and cross products for each pair of the four variables. The four dependent variables (creativity of the final solutions to the two problems and the number of suggestions during the Production Phase to these two problems) correlated negligibly among themselves. The highest correlation between any pair of these four variables, when averaged within groups, was .28 (not significant). The remaining intercorrelations ranged from .13 to —.26. The lack of significant intercorrelation between the production indices and creativity suggests that the effects of the evaluation variable upon the final solutions cannot be attributed to the increase in the number of suggestions during the Production Phase. As an additional check, however, an analysis of co-variance, in which both production indices were partialled out, did not affect the significant effect of evaluation upon creativity of the final solutions.

Contents of the final solutions.—Content analyses of the final solutions to the two experimental problems suggested that the independent variables may affect the content of the answers as well as their judged quality. In the Automatic Warehousing Problem the most common solution involved marking the boxes in some fashion: color coding, magnetic ink, magnetic tape, etc. Despite the commonness of such solutions (as many as 18 *S*s produced a solution in this category), all the solutions that were rated high in creativity were of this kind. (Of course, many of the marking solutions received low ratings because of poor quality). The number of such marking solutions seemed to vary with the evaluational input—13 *S*s in the Constructive Groups came up with such a solution as compared with only 5 *S*s in the Critical Groups ($p = .02$, two-tailed, by Fisher's exact test).

The results are not so clearly related to the experimental input in the case of the Pyroelectric Effect, but to the extent that they show anything they seem to reveal an influence of the informational rather than the evaluational input. As many as 20 *S*s produced solutions that suggested using the effect for temperature sensing or temperature regulation. Of these solutions, 13 were produced by *S*s in the Homogeneous Condition and 7 were produced by *S*s in the Heterogeneous Condition ($p = .09$, two-tailed, by Fisher's exact test).

Discussion

The present experiment began with the working hypothesis that an individual's attitude at the time he stores relevant information affects his subsequent problem solving. The results support this hypothesis.

Further support for the effect of induced attitude upon creativity comes from an experiment by Torrance (1959). As one assignment in an educational psychology course, Torrance instructed half of his class to review "creatively" articles in the professional journals, i.e., to look for new possibilities in the reported findings. He instructed the other half of his class to review "critically" articles in the professional journals, i.e., to point out defects and limitations. The effects of the assignment apparently carried over to the students' individual term projects. The students in the creative condition turned in projects which were rated significantly more creative than those turned in by the students in the critical condition. In a subsequent experiment, Torrance and Harmon (1960) instructed their students to adopt one of three different reading sets (memory, evaluation, creative application) and these sets were rotated among the students after each week's assignment. The students "operating under the creative set, achieved the highest mean each week on the creative applications."

The results of Torrance and those of the present *E* pose an interesting question. We have shown that an individual's attitude toward prior information affects the way he handles subsequent problems. But now the question arises

as to how attitude and information combine to produce the observed effects. Do the evaluation and information represent two independent inputs whose effects summate? Or do they interact, with the attitude operating to positively or negatively reinforce the given information?

Because the interaction between evaluation and information was insignificant for both problems, the results of this experiment might be taken as support for the hypothesis of two independent inputs. To the extent that such independence is actually the case, it implies that the induced attitude, once established, operates independently of the information upon which it was established. The fact that in Torrance's experiment and in the present one the induced attitude transferred to problems which are apparently unrelated to the prior information further supports the hypothesis of independence.

But the lack of interaction in the present experiment must be viewed with reservation because the effects of the informational variable were also insignificant. It might very well be, when information is varied in other ways, both main effects and interactions will occur. Moreover, there are strong theoretical reasons for expecting attitude and information to interact. This *E*, viewing the evaluation variable as a way of reinforcing the evaluated information, expected the Constructive Condition to activate or make more available for later use the evaluated information and related responses. [Such an expectation is based on theoretical considerations such as those offered by Maltzman (1955) and Cofer (1957).] He predicted, for example, that the Constructive Condition would operate upon the Heterogeneous Input to make a variety of response systems available for subsequent problem solving; and this greater availability of response systems would result in a more creative solution. Although the HECO condition did, in fact, result in the greatest creativity on the Pyroelectric Effect, the corollary of this expectation—that the HECR should result in the lowest creativity—did not occur. Thus, whether the Constructive Condition sets up a highly generalized set which is independent of informational content or whether it reinforces certain response systems and changes the order of dominance among hierarchies of responses, remains an intriguing question for future experiments.

Another question raised by the present experiment concerns the relationship of the Production Phase to the Solution Phase. Although the Constructive Condition apparently facilitates the quantity of suggestions as well as the quality of the final solution, the statistical analyses suggest that the effects upon production and solution are independent rather than interdependent. This latter finding, in turn, raises the question for future research whether the changes in creativity can be explained in terms of alterations in the availability of responses or in terms of shifts in *S*s' standards for selecting a solution from his available alternatives.

The present data, for example, hint that the effects upon the final solutions may come about through a shift in *S*s' criteria for choosing a solution. This hint comes from an analysis of the intercorrelations between the rated creativity and *S*'s own ratings of satisfaction with a given solution. The average correlation between these two types of ratings on the Pyroelectric Effect Problem, for example, was — .46 within the Constructive Groups and .42 within the Critical Groups. This difference, which is significant at the .01 level, would suggest, if it is replicated in future experiments, that the evaluation variable has brought about a shift in the kind of solution which *S* is trying to achieve.

Many other questions, of course, are raised by this initial experiment upon the effects of attitude and information. Some of the questions (concerning the dimensions along which the informational effects generalize; the unravelling of the effects of amount, content, and quality of the given information) stem directly from the questions which were just discussed. Other issues (concerning open-ended vs. single-answered problems; the effects of overloading and saturation; the combination of constructive and critical attitudes in discrimination training) deal with the nature of the problem and extend the range over which the variables are varied.

Fortunately, many, if not all, of the questions which have been raised in this discussion can be tackled experimentally. Moreover, they can be investigated with the same procedures for varying information and the way it is stored that were employed in the present experiment. In pursuing the answers to these questions, this *E* feels that we may gain new insights into how individuals organize, transform, and use information in their problem-solving behavior.

SUMMARY

An experiment was conducted to provide information on how prior information affects creativity both on related and unrelated problems. Both the content of, and the way *S* encoded, prior information were varied by means of an Evaluation Task. In this task, *S* was given a set of four solutions to an an evaluation task. In this task, *S* was given a set of four solutions to an Automatic Warehousing Problem, either a Heterogeneous or a Homogeneous set, to evaluate constructively or critically. Following this evaluation task, *S* was asked to provide his own solution to the Automatic Warehousing Problem as well as a solution to an entirely new problem.

*S*s in the Constructive Condition produced solutions, on both the related and unrelated problems, which were rated significantly more creative. Although the effects of the informational variable were non-significant, they tend to indicate that the Heterogeneous Condition may have facilitated creativity on the Pyroelectric Effect Problem and hindered it on the Automatic Warehousing Problem.

These findings raise the question as to how the attitude and informational

variables combine to produce the observed effects. One possibility, partially supported by the present data, is that the information and the way it is assimilated produce two independent and summating effects. A second possibility, more in line with theoretical expectations, is that the two variables interact, which, if true, should result in a shift in dominance among response hierarchies. The question of how the variables combine, as well as others raised by the present experiment, can be investigated with substantially the same experimental procedures that were employed in the present investigation.

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Accepted June 13, 1961.